Outlooks & business implication of Bluetooth and future of Bluetooth

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Abstract

Bluetooth is a new short-range wireless technology designed to enable wireless communication between diverse devices. It is gaining increasing popularity and acceptance in the world today. There is a growing body of research on the subject, but very few, if any of the analyses, provide a balanced view of the technology, which describe its pros and cons and implications for businesses. [1] Handheld devices are rapidly becoming an integral part of our daily lives, and many road warriors already carry a cell phone, palmtop, and laptop computer with them. In most cases, these devices do not have compatible data communication interfaces, or, if they do, the interface requires cumbersome cable connections and configuration procedures. An obvious solution is to get rid of the cables and use short-range wireless links to facilitate on-demand connectivity among devices. An ideal solution would also be inexpensive, enabling of compelling applications, and universally adopted by device vendors. [2]. BLUETOOTH is new emerging wireless technology capturing the minds of present day technologists, which integrates a wide variety of portable devices (PDA, digital cameras, printers etc), called enabled devices. This paper deals with few new Bluetooth application domains, in addition to those already being developed as new profiles within the Bluetooth Special Interest Group (SIG). These go beyond the cable replacement scenarios included in the version 1.x Bluetooth specification and include such domains as medical, mobile e-commerce, and home networking [8].

Keyword: *Bluetooth technology, comparison with other, outlooks & business implication, application & future of Bluetooth.*

1. Introduction

The word "Bluetooth" is an anglicized version of the Scandinavian Blåtand/Blåtann, the epithet of the tenth-century king Harald I of Denmark and parts of Norway who united dissonant Danish tribes into a single kingdom. The idea of this name was proposed in 1997 by Jim Kardach who developed a system that would allow mobile phones to communicate with computers [6]. The Bluetooth Special Interest Group (SIG) was founded by Ericsson, IBM, Intel, Nokia, and Toshiba in February 1998 to develop an open specification for short-range wireless connectivity. The group is now also promoted by 3COM, Microsoft, Lucent, and Motorola. More than 1900 companies have joined the SIG.[5] Bluetooth was standardized as IEEE 802.15.1, but the standard is no longer maintained. The SIG oversees the development of the specification, manages the qualification program, and protects the trademarks [6]. The implication is that Bluetooth does the same with communications protocols, uniting them into one universal standard. The Bluetooth logo is a bind rune merging the Younger Futhark runes ᚼ (Hagall) (ᚼ) and ᛒ (Bjarkan) (ᛒ), Harald's initials. [6]. The Bluetooth technology is relatively new as compared to other technologies and there is huge potential of its growth and practical application. Therefore in this paper I try to analysis the current status of this technology and issue which are related to this technology [7]. This paper begins with a microanalysis of Bluetooth by describing the technical details such as Bluetooth component, Bluetooth technical summary, power specification, Bluetooth protocol stack, Bluetooth network, connectivity, error control methods. The subsequent section describes macroanalysis which include Bluetooth application, comparison with other technology, Bluetooth advantages & disadvantages. Next section describes outlooks and business implication .Last section explain future of Bluetooth and future growth of Bluetooth & finally conclusion.

2. Bluetooth technology: a microanalysis

Bluetooth technology permits devices to communicate with each other, synchronize data, and connect to the Internet at high speeds without

wires or cables. A Bluetooth radio and baseband controller can be installed on a device that links to a Universal Serial Bus (USB) port, a PC Card, or integrated on a system board
to add Bluetooth functionality to a computer or other host device, as shown in fig.1 [1]. Bluetooth operates in the range of 2400–2483.5 MHz (including guard bands). This is in the globally unlicensed Industrial, Scientific and Medical (ISM) 2.4 GHz short-range radio frequency band. Bluetooth uses a radio technology called frequency-hopping spread spectrum (FHSS). The transmitted data is divided into packets and each packet is transmitted on one of the 79 designated Bluetooth channels. Each channel has a bandwidth of 1 MHz. The first channel starts at 2402 MHz and continues up to 2480 MHz in 1 MHz steps. It usually performs 1600 hops per second, with Adaptive Frequency-Hopping (AFH) enabled [6].

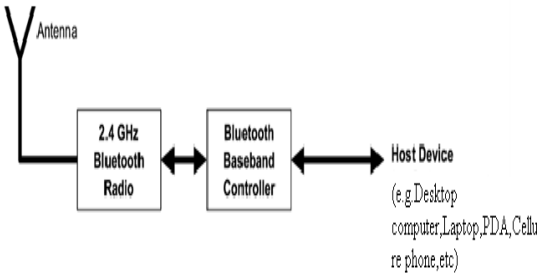

Fig.1 Bluetooth component

2.1 Technology overview

Bluetooth is an industry standard, later adopted by the IEEE 802.15 work group as the Wireless Personal Area Network Standard (WPAN). To clearly understand this, I need to understand what a PAN is. A Personal Area Network can be defined as a network of devices in close range to a person, which can communicate with each other. A typical PAN could consist of a Laptop, a Mobile Phone and a Printer as shown in fig.2.

Fig.2 Bluetooth usage scenarios

Bluetooth is a packet-based protocol with a master-slave structure. One master may communicate with up to 7 slaves in a piconet; all devices share the master's clock. Packet exchange is based on the basic clock, defined by the master, which ticks at 312.5 µs intervals. Two clock ticks make up a slot of 625 µs; two slots make up a slot pair of 1250 µs. In the simple case of single-slot packets the master transmits in even slots and receives in odd slots; the slave, conversely, receives in even slots and transmits in odd slots. Packets may be 1, 3 or 5 slots long but in all cases the master transmit will begin in even slots and the slave transmit in odd slots.[6]A typical single-slot frame hops at 1600 hops/s. Multislot frames will allow higher data rates because of the elimination of the turnaround time between packets and the reduction in header overhead. For example, single-slotpackets can have a maximum data rate of 172 kbps, while a five-slot, one-multislot frame will support a 721-kbps rate in the five-slot direction with a 57.6- kbps rate back channel in the one-slot direction [1].

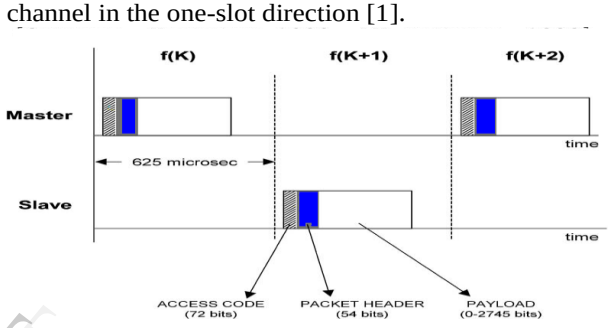

Fig.3 Bluetooth frame

2.2 Technical summary

In this section I summarize technical parameter related to Bluetooth. Like most wireless technologies, Bluetooth is fairly sophisticated and hence the complete technical specification is very vast. I identify some key technical features of this technology which actually makes it so interesting. Below table no.1 shows technical summary of Bluetooth [7].

Table No. 1 Technical Specification

Sr. No	Item (Parameter)	Specification
1	Connection	Spread Spectrum(Frequency Hopping)
2	Frequency Band	2.4 GHZ ISM
3	Modulation Technique	Gaussian Frequency Shift keying (GFSK)
4	MAC Scheduling	FH-CDMA
5	Aggregate Data Rate	0.721-1 Mbps
6	Range	10m-100m
7	Supported Stations	8 Devices (Per Piconet)
8	Voice Channels	3
9	Data Security-Authentication Key	128 bit key
10	Data Security-Encryption key	8-128 bits(configurable)

Originally Gaussian frequency-shift keying (GFSK) modulation was the only modulation scheme available; subsequently, since the introduction of Bluetooth 2.0+EDR, π/4-DQPSK and 8DPSK modulation may also be used between compatible devices. Devices functioning with GFSK are said to be operating in basic rate (BR) mode where an instantaneous data rate of 1 Mbit/s is possible. The term Enhanced Data Rate (EDR) is used to describe π/4 DPSK and 8DPSK schemes, each giving 2 and 3 Mbit/s respectively. The combination of these (BR and EDR) modes in Bluetooth radio technology is classified as a "BR/EDR radio"[6].

2.3 Power Classes

Table No. 2 Power Classes

Sr. No.	Class	Maximum Permitted Power (mW)	dBm	Range(meter)
1	Class 1	100	20	100
2	Class 2	2.5	4	10
3	Class 3	1	0	1

Most Bluetooth applications are in indoor conditions, where attenuation of walls and signal fading due to signal reflections will cause the range to be far lower than the specified line-of-sight ranges of the Bluetooth products. Most Bluetooth applications are battery powered Class 2 devices, with little difference in range whether the other end of the link is a Class 1 or Class 2 device as the lower powered device tends to set the range limit. In some cases the effective range of the data link can be extended when a Class 2 devices is connecting to a Class 1 transceiver with both higher sensitivity and transmission power than a typical Class 2 device,mostly however the Class 1 devices have a similar sensitivity to Class 2 devices. Connecting two Class 1 devices with both high sensitivity and high power can allow ranges far in excess of the typical 100m, depending on the throughput required by the application. Some such devices allow open field ranges of up to 1km and beyond between two similar devices without exceeding legal emission limits. In above table2 shows power classes[6].

Table No. 3 Version of Bluetooth

Sr. No.	Version	Data Rate	Maximum Appplication throughput
1	Version 1.2	1 Mbit/s	>80 kbit/s
2	Version 2.0 + EDR	3 Mbit/s	>80 kbit/s
3	Version 3.0 + HS	24 Mbit/s	Maximum

While the Bluetooth Core Specification does mandate minima for range, the range of the technology is application specific and is not limited. Manufacturers may tune their implementations to the range needed for individual use cases. Table 3 shows particular version and their data rate with maximum application throughput [6].

2.4 Protocol Stack of Bluetooth

A Protocol stack is Software/ Hardware implementation of the actual protocols specified within a standard which enables the devices based on that standard communicate with each other. The Bluetooth protocol stack is as shown in Figure 4 [7].

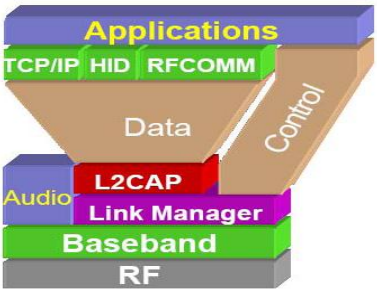

Fig.4 Protocol Stack of Bluetooth

Bluetooth is defined as a layer protocol architecture consisting of core protocols, cable replacement protocols, telephony control protocols, and adopted protocols. Mandatory protocols for all Bluetooth stacks are: LMP, L2CAP and SDP. In addition, devices that communicate with Bluetooth almost universally can use these protocols: HCI and RFCOMM [6]. The information about the layer is given below;

i) LMP

The Link Management Protocol (LMP) is used for set-up and control of the radio link between two devices. Implemented on the controller.

ii) AVRCP

A/V Remote Control Profile. Commonly used in car navigation systems to control streaming Bluetooth audio. Adopted versions 1.0, 1.3 & 1.4.

iii) L2CAP

The Logical Link Control and Adaptation Protocol (L2CAP) Used to multiplex multiple logical connections between two devices using different higher level protocols. Provides segmentation and reassembly of on-air packets.

iv) RFCOMM

Radio Frequency Communications (RFCOMM) is a cable replacement protocol used to create a virtual serial data stream. RFCOMM provides for binary data transport and emulates EIA-232 (formerly RS-232) control signals over the Bluetooth baseband layer, i.e. it is a serial port emulation .RFCOMM is a simple, reliable transport protocol with framing, multiplexing and the following additional provisions [7].

• Modem status- RTS/CTS, DSR/DTR, DCD, ring.
• Remote line status-Break, overrun, parity.
• Remote port settings-Baud rate, parity, number of data bits, etc..
• Parameter negotiation (frame size).
• Optional credit based flow control.

Adopted protocols are defined by other standards-making organizations and incorporated into Bluetooth's protocol stack, allowing Bluetooth to create protocols only when necessary. The adopted protocols include:

a) Point-to-Point Protocol (PPP)
Internet standard protocol for transporting IP datagrams over a point-to-point link.
b) TCP/IP/UDP
Foundation Protocols for TCP/IP protocol suite.
c) Object Exchange Protocol (OBEX)
Session-layer protocol for the exchange of objects, providing a model for object and operation representation.

Wireless Application Environment/Wireless Application Protocol (WAE/WAP) WAE specifies an application framework for wireless devices and WAP is an open standard to provide mobile users access to telephony and information services [6].

2.5 Bluetooth Networking

Bluetooth communication is made possible by establishing a master device and one or more slave devices. Any device can be a master or a slave. It is this property which makes Bluetooth useful for creating ad-hoc networks. One of the most important features of Bluetooth is that unlike WLAN any Bluetooth device can communicate with other device in range by simply establish one of them as the master and rest as slaves. The master device determines the frequency hopping pattern based on its address. There are two different topologies through which Bluetooth communication occurs [7].

1. Piconet
2. Scatternet

2.5.1 Piconet

Piconet is ad-hock network in which all the devices have the same frequency hopping synchronization. Each Piconet has one master and one or more than one slave devices. A master is the only one that may initiate communication. When link is established, the slave may request to the master to become a master. The master is responsible for dividing the whole bandwidth amongst the slaves by deciding when and how to communicate with each other. Each Piconet can have 8 active devices addressed by 3 bits and 248 parked devices addressed with 8 bits and several more in standby. This intelligent use of device states in what makes networking in Bluetooth interesting. The active devices as the name suggests actively participate in the network while the parked devices can be initiated under 3 milli-seconds. Hence in a network where several devices need to communicate with each other, devices can be pushed to parked and active state intelligently by the master to enable effective networking. One Piconet can be split into two piconets by one slave becoming a master and thus may increase the aggregate throughput. It is this splitting which is seen as the overlapping area in the Figure5 [7].

2.5.2 Scatternet

Scatternet is the overlapping areas among multiple piconets. A master can leave its Piconet and can join another Piconet as a slave. Scatternet is used to optimize the use of the available spectrum. The entire units share the same frequency range within one scatternet but each Piconet uses different hope sequence to avoid interference with each other. A clever way to optimize the transmission data capability is to keep the piconets small . All piconets share the 79 MHz band where each Piconet uses 1MHz .As long as the piconets picks different hope frequencies, no sharing of 1 MHz hop channels occur [7].

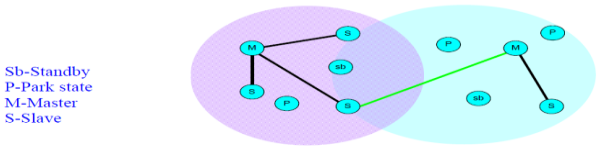

Fig.5 A scattered comparing two piconets [7].

2.6 Baseband error correction

Depending on packet type, individual packets may be protected by error correction, either 1/3 rate forward error correction (FEC) or 2/3 rate. In addition, packets with CRC will be retransmitted until acknowledged by automatic repeat request (ARQ).

3. Bluetooth technology: a macroanalysis

Bluetooth's versatility enables its use in a wide range of mobile digital devices. Several vendors have Bluetooth equipped devices available today and many more have products in the planning and development stages. description of these applications is presented below. Bluetooth is not the only contender for wireless connectivity. Strong competition exists from IrDA, Ultra Wideband Radio, HomeRF etc. This section discusses the predominant issues for Bluetooth and their possible impact [1].

3.1 Bluetooth application

The initial applications of Bluetooth include wireless connectivity between computing and mobile devices like PCs, MP3 players, PDAs, and mobile phones, but eventually it will lead to a host of consumer electronic devices like wrist watches, sound systems and speakers, TVs, microwaves, camcorders. This would enable these devices to be in a continuous contact between each other and enable them to share their resources [1].
A typical Bluetooth mobile phone headset

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- Wireless control of and communication between a mobile phone and a hands free headset. This was one of the earliest applications to become popular [6].
- Wireless control of and communication between a mobile phone and a Bluetooth compatible car stereo system [6].
- Wireless Bluetooth headset and Intercom[6]
- Replacement of previous wired RS-232 serial communications in test equipment, GPS receivers, medical equipment, bar code scanners, and traffic control devices [6].
- Wireless bridge between two Industrial Ethernet (e.g., PROFINET) networks [6].
- Three seventh and eighth generation game consoles, Nintendo's Wii.and Sony's PlayStation 3, PSP Go and PS Vita, use Bluetooth for their respective wireless controllers [6].
- The Bluetooth wireless technology3 will serve primarily as a replacement of the interconnect cables between a variety of personal devices, including notebook computers, cellular phones, personal digital assistants (PDAs), digital cameras,etc [4].
- The impact on businesses and consumers could be dramatic. In Bluetooth-networked stores, for example, users might be able to synchronize their shopping lists with a current map of the store and get directions to each item. They could also make purchases by accessing Internet-based payment systems on their hand-held computers. Hotel guests could more easily use equipment such as printers at a business center [1].
- In-home networks are becoming more common as people want to enhance their convenience, security and safety at home and use their personal devices in home environments (as well as elsewhere). Bluetooth technology can be especially useful in home networks because it does not require any wires to be installed in the home to allow devices to communicate [8].

3.2 Bluetooth and other wireless technologies (comparison) [7]

There are several wireless technologies which have various applications. Some of these technologies offer the similar features and use cases as Bluetooth. The table 4 compares various wireless technologies based on different characteristics. By comparing information from the Table 4, I can see that although there are several wireless technologies with applications overlapping with Bluetooth .They all have certain limitations and do not cover all areas as Bluetooth.

3.3 Bluetooth advantages & disadvantages [11]

The advantages and disadvantages of Bluetooth technology are well-known to anyone who extensively uses Bluetooth for transferring data or sharing information. IEEE standards govern its networks and have standardized it for use with a vast range of compatible devices.

3.3.1 Advantages of Bluetooth [11]

- Bluetooth does not require a clear line of sight between the synced devices. This means that the devices need not be facing each other, and it is also possible to carry out transfers when both the devices are in separate rooms.

The fact that this technology requires no cables and wires is something that has made it so popular. With so many devices engulfing our lives today,

the need for clutter-free technology is becoming more intense.

- The maximum range that it offers is 100 meters, but this range is not the same for all similar connections. It depends on the nature of the devices and the version that they operate upon.
- The processing power and battery power that it requires in order to operate is very low. This makes it an ideal tool for so many electronic devices, as the technology can be implemented pretty much anywhere.
- One major advantage is its simplicity of use. Anyone can figure out how to set up a connection and sync two devices with ease. Moreover, the technology is completely free to use and requires no charges to be paid to any service provider.
- The chances of other wireless networks interfering with yours are very low. This is because of the low powered wireless signals that the technology adopts, and also because of something known as frequency hopping.

3.3.2 Disadvantages of Bluetooth [11]

- Though the transfer speeds are impressive at around 1 Mbps, certain other technologies like Infrared can offer speeds up to 4 Mbps. This is an area that can be improved on in the near future
- Even though the security is good, it is even better on Infrared. This is because of the comparatively larger range of Bluetooth and also the lack of a line of sight. Someone who knows how to hack such networks can do so eventually.
- The battery usage during a single transfer is negligible, but there are some people who leave the device switched on in their devices. This inevitably eats into the battery of these devices, and lowers the battery life considerably.

4. Outlooks and business implication

4.1 Outlooks of Bluetooth

4.1.1 Bluetooth is the right technology for mHealth

Today there is a broad interest in electronic medical records and in the potential for mobile healthcare (mHealth) to provide more accurate, more pervasive health data. As a general model for personal medical monitoring systems, users either have on-body or inbody sensors that send the data wirelessly to an aggregator device, which usually is envisioned as a mobile phone. Users can then share that data with their doctor by sending it directly or by uploading the data to a server.[2]

4..1.2 Travel

The travel industry is always seeking new ways to save time and enhance convenience for travelers. Here we present a few ways in which Bluetooth wireless technology could enhance travel scenarios. In the airline industry, the use of so-called "ticketless travel," or electronic tickets, is becoming more common. Self-service check-in kiosks are beginning to appear in airports. However, electronic tickets still require issuance of a paper boarding pass in many cases, and self-service check-in often requires the use of a credit card or frequent flyer card to identify the user. With a personal device that employs Bluetooth wireless communications, a traveler might check in using this device, which could include personal identity credentials, thus eliminating the need to insert a card into a terminal. Moreover, an electronic boarding pass could be issued and stored in the Bluetooth device; that same device could then be used to wirelessly present the boarding pass when boarding the aircraft, eliminating the need for a paper boarding.[8]

4.1.3 Smartphone Accelerometer Controlled Automated Wheelchair

Wheelchair bound patients in many countries are still dependent on other people for movement. Though automated wheel chairs are available, they are tough to operate and are power consuming. Smart phones and Bluetooth wireless technology enabling patients to move their wheelchairs by just tilting their Smartphone [5].

4.2 Business implications of Bluetooth

Electronic wireless sensors could cut medical costs by enabling physicians to remotely monitor vital signs such as blood pressure, blood glucose, and blood oxygenation while patients remain at home. According to the IDC report “Worldwide Bluetooth Semiconductor 2008-2012 Forecast,” published November 2008, a forthcoming radio frequency communication (“wireless connectivity”) standard, Bluetooth low energy, will link wireless sensors via radio signals to the 70% of cell phones and computers likely to be fitted with the next generation of Bluetooth wireless technology, leveraging a ready-built infrastructure for data transmission. Analysis of trends indicated by this data can help physicians better manage diseases such as diabetes. The technology also addresses the concerns of cost, compatibility, and interoperability that have previously stalled widespread adoption of wireless technology in medical application[10].

Bluetooth has a promising future ahead because it meets a basic need of connectivity in close proximity.
Since the formation of the original SIG, more than 1800 manufacturers worldwide have joined the initiative worldwide. According to one market research report, Bluetooth technology is expected to be built into over 100 millions devices before the end of 2005. Still, according to another report from market research
firm Cahners In-Stat Group, there will be over 670 million Bluetooth-enabled devices worldwide by 2010 [1].

5. Future of Bluetooth & future growth of Bluetooth

5.1 future of Bluetooth

1] In the hotel industry, the use of Bluetooth technology has been demonstrated at industry trade shows. Possible applications of Bluetooth wireless communication include the ability to check in to the hotel automatically using a Bluetooth device (perhaps via a kiosk, without visiting the front desk), retrieving guest messages using Bluetooth links and enabling in-room information services such as telephones, Internet access devices, printers, fax machines and so on with Bluetooth wireless communication, allowing them to be used with personal portable devices that the hotel guest brings along. Even the use of Bluetooth wireless communications to open special Bluetooth door locks on hotel room doors has been demonstrated.[8]
2] Any terminal that is used for retail transactions could incorporate Bluetooth wireless technology and thus connect to other Bluetooth devices to complete retail transactions. For example, a mobile phone could connect to a soda machine over a Bluetooth link to pay for a soda, or link to a kiosk at which you could buy a theater ticket. Similarly, a mobile phone, PDA, or other device could be used to pay for goods and services using Bluetooth communication links with a cash register. Indeed, through the use of Bluetooth access points, entire shopping malls, arenas, grocery stores, restaurants, and other retail areas could allow customers to perform financial transactions throughout the building. Along with electronic payment, related transactions could occur, including such things as special discounts, electronic coupons, customer loyalty benefits and so on [8].
3] If many devices in the home (including devices such as audiovisual equipment, appliances, home security, and automation systems) happen to have Bluetooth interfaces, a personal device such as a PDA or mobile phone might be used as a "universal remote control" for all of these other devices. From a single device, using Bluetooth links, a person might be able to receive alerts that the refrigerator door was left open or the clothes dryer completed a cycle, arm the security system, control lighting in the house, and control the stereo and television.

5.2 Future growth of Bluetooth

1] "BlueDAT" digital audio platform is presented, which employs the Bluetooth wireless technology for real-time, CD-like quality, stereo reproduction. It is shown that, despite the strict throughput limitations imposed by the Bluetooth protocol, the BlueDAT application setup can efficiently accommodate cable-free, high-quality audio streaming and playback over one or two receivers for home environments, through the employment of a set of novel mechanisms for the automatic adaptation of both the transmission rate and the audio coding bitrate [9]
2] Wireless medical monitoring with Bluetooth low energy will initially be targeted at BG (Blood Glucose) measurement, but applications such as body temperature, blood pressure, pulse oximetry, and heart rate will follow shortly after. However, Bluetooth low energy is a new technology, and medical products equipped with it are unlikely to appear before 2011 [10]

Fig 6 A BG meter measures BG levels from a

sample deposited on a test strip.
Modern units store information in a memory base for later recall at regular health checks.[10]

5.3Future Developments

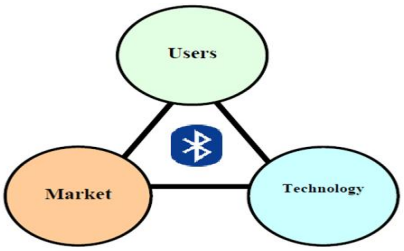
1] Ultra Wide Band (UWB)
One of the primary reasons for the success of Bluetooth is the fact that it is a standard developed and constantly upgraded by the Bluetooth Special interest Group (SIG). Bluetooth has constantly evolved from Bluetooth version 2.0 to the latest version 3.0 with enhanced data rate (EDR), which increases data rate from 24Mbps to 3 Mbps and the overall transmission rate to 3 Mbps. The new specification also aims to reduce power consumption further by 50 %. However one of the most important future developments in Bluetooth would be the incorporation of Ultra Wide Band (UWB) radio technology in Bluetooth. The

Bluetooth SIG and the UWB work groups have decided to collaborate and work together to make this happen.[7]

2] sensors & Personal tags

The cost of Bluetooth chipsets is fast reducing and further decrease together will decrease in power consumption will enable its use in disposable sensors ,Personal tags etc . A pilot Project in this regard has been demonstrated at the Zoological Park in Denmark. Children visitors at the Zoo are given Bluetooth enabled tags which will help parents determine their location in Zoo, thus ensuring children's safety Similarly Bluetooth enabled sensors and communication devices are used in the city of Oslo to monitor critical water levels at pumping stations.

6. Conclusion.



BLUETOOTH is likely to rule the communication scenario in the coming years. It will be one of the key technologies for the wireless networking at home and offices. Since BLUETOOTH enabled devices do not require line of sight operation, many interesting applications based on BLUETOOTH technology are likely to come up. In the future, Bluetooth is likely to be standard in tens of millions of mobile phones, PCs, laptops, and a whole range of other electronic devices. As a result, the market is going to demand new innovative applications, value-added services, end-to-end solutions, and much more. The possibilities opened up really are limitless, and because the radio frequency used is globally available, Bluetooth can offer fast and secure access to wireless connectivity all over the world. With potential like that, it's no wonder that Bluetooth is set to become the fastest adopted technology in history.

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Table 4 comparison with Bluetooth

category	Bluetooth	IrDA	Home RF	IEEE802.11
Purpose	Cable/WPAN	Cable	Home	WLAN
Technology(2.4 GHz)	FHSS	850nm	FHSS	FHSS/DSSS
Powe(dB/m)	0-20	low power	0-20	20
Data Rate (Mbps)	1	0.115/4	0.8/1.6	11
Distance(meter)	10-100	3/5		30-100
Topology(Device)	8	10	8	128
Security	Authentication * Encryption	Application layer	Optional	Optional WFP
Data and Voice	Data and Voice	Data Only	Data Only	Data Only
Medium	RF/Omni-directional	Optical/Directional	RF/Omni-directional	Directional